EXHIBIT C

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March 17, 2015

Via Certified Mail

Mr. Joey Underwood
Senior Vice President
41 Stevens Street
Greenville, SC 29605

Re: Safety Components' Infringement of U.S. Patent No. 8,898,821

Dear Mr. Underwood:

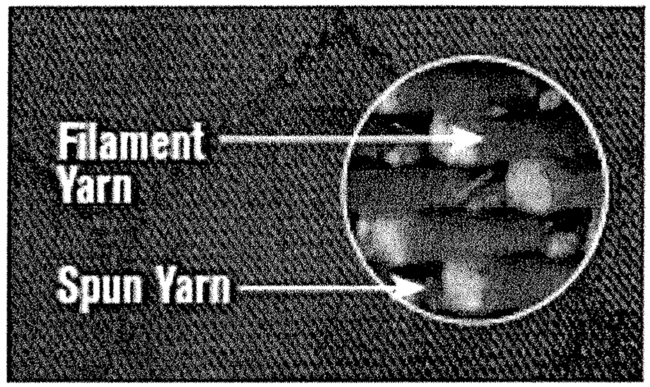
We represent Southern Mills, Inc. d/b/a TenCate Protective Fabrics USA ("TenCate"). TenCate owns U.S. Patent No. 8,898,821 (the "821 Patent"), entitled "Flame resistant fabrics with anisotropic properties," which issued on December 2, 2014. A copy of the 821 Patent is attached for your reference.

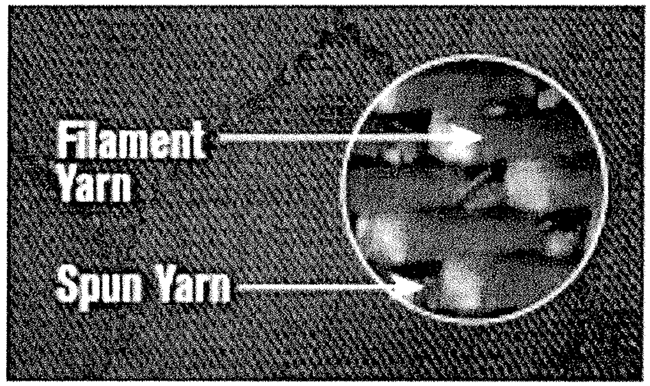
Safety Components is currently offering for sale, manufacturing and selling several types of flame resistant thermal liners under the Glide™ trade name. This activity infringes the 821 Patent.[1]

A Product Guide for Safety Components' Glide™ product is attached, as downloaded from the Glide™ product page on Safety Components' website.[2] TenCate believes that the face cloth in Safety Components' Glide™ product is covered by claims of the 821 Patent. Below, we provide a claim chart for claim 1 of the 821 Patent as an example of how the Glide™ Product is covered by the patent:

Claim 1	Glide™ Product Guide
1. A flame resistant fabric formed of warp yarns and fill yarns and comprising a body side and a face side, wherein:	The Glide™ face cloth is formed of: • 60% DuPont™ Kevlar® (para-aramid) filament fibers, and • 40% spun yarn comprising a blend of Dupont™ Nomex® (meta-aramid) and Lenzing FR® (flame resistant viscose/rayon) staple fibers.

[1] It is our understanding that TenCate's infringement concerns were relayed to you at least on October 17, 2014 and February 19, 2015 by Daniel Hauert and resulted in licensing negotiations of the 821 Patent for your Glide™ products. No licensing arrangement was ever reached.
[2] Downloaded on March 11, 2015.

	(p. 2). The face cloth is formed entirely of flame resistant fibers and is a flame resistant fabric. The face cloth is a woven fabric having warp yarns and fill yarns and having a face side (facing the quilted layer(s)) and a body side (referred to as the "surface of the fabric"), as evidenced by Fig. 1 (p. 2):  **Fig.1: Glide**
(a) either of the warp yarns or the fill yarns comprise a first fiber content;	Either the warp or the fill yarns comprise 100% Kevlar® (para-aramid) filament fibers (fibers of a first fiber content). (p. 2). See also Fig. 1 (Id.).
(b) the other of the warp yarns or the fill yarns comprise a second fiber content different from the first fiber content;	The other of the warp yarns or the fill yarns comprise 100% spun yarns comprising a blend of Nomex® (meta-aramid) and Lenzing FR® staple fibers (fibers of a second fiber content different from the Kevlar® para-aramid fibers in the first fiber content). (p. 2).
(c) fibers of the first fiber content are predominantly exposed on a body side of the fabric;	The Kevlar® fibers (first fiber content) are predominantly exposed on the body side of the fabric (i.e., facing the wearer). See Fig. 1 (p. 2):

	 **Fig. 1: Glide** Fig. 1 shows the Kevlar® (para-aramid) filament yarns and spun yarns arranged in a 2x1 twill construction, which would predominantly expose more of the para-aramid filament yarns on one side of the fabric than the other. In addition, "[a] microscopic analysis shows Glide (Fig. 1) with an abundance of strategically woven DuPont Kevlar filament of the surface of the fabric—a combination leading to significant advantages in slickness for freedom of movement, lubricity for comfort, and strength for durability." (p. 2).
(d) fibers of the second fiber content are predominantly exposed on a face side of the fabric; and	The spun yarns (fibers of the second fiber content), which are less exposed on the body side of the fabric, are predominantly exposed on the back side (i.e., face side) of the fabric, facing away from the wearer and towards the quilted layer(s).
(e) the fabric comprises at least 10% para-aramid fibers and more of the para-aramid fibers are located in the first fiber content than in the second fiber content.	The face cloth comprises 60% Kevlar® (para-aramid) filament fibers. (p. 2). More of the para-aramid fibers are located in the first fiber content, which contains the 100% Kevlar® filament fibers, than the second fiber content, which contains the 100% spun yarns which contain only Nomex® and Lenzing FR® staple fibers (i.e., does not contain any para-aramid fibers).

For at least the reasons set forth above, Safety Components' Glide™ face cloth fabrics are covered by at least claim 1 of the 821 Patent. The claim chart above is merely representative and in no way should be construed as limiting TenCate's ability to assert additional claims of the 891 Patent or the 891 Patent against other of your products.

While TenCate takes seriously any and all infringement of its intellectual property rights, the company is interested in exploring whether a mutually acceptable license arrangement concerning the 821 Patent can be reached. Please contact us at your earliest convenience to discuss such an arrangement and in no event later than March 24, 2015.

Sincerely,

Kristin J. Doyle

Enclosures

45634/891955

US008898821B2

(12) **United States Patent**
Stanhope et al.

(10) **Patent No.: US 8,898,821 B2**
(45) **Date of Patent: Dec. 2, 2014**

(54) **FLAME RESISTANT FABRIC WITH ANISOTROPIC PROPERTIES**

(75) Inventors: **Michael T. Stanhope**, Atlanta, GA (US); **Charles S. Dunn**, Griffin, GA (US); **Matthew Lucius Colatruglio**, Roswell, GA (US)

(73) Assignee: **Southern Mills, Inc.**, Union City, GA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/303,495**

(22) Filed: **Nov. 23, 2011**

(65) **Prior Publication Data**

US 2012/0090080 A1 Apr. 19, 2012

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/783,368, filed on May 19, 2010, now abandoned.

(60) Provisional application No. 61/179,461, filed on May 19, 2009.

(51) **Int. Cl.**

A62B 17/00	(2006.01)
D02G 3/44	(2006.01)
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A41D 31/00	(2006.01)

(52) **U.S. Cl.**

CPC ***D03D 15/12*** (2013.01); *D10B 2201/22* (2013.01); *D10B 2403/011* (2013.01); *D10B 2331/021* (2013.01); ***D02G 3/443*** (2013.01); *D10B 2201/28* (2013.01); *D10B 2201/01* (2013.01)

USPC **2/458**; 2/81; 2/7; 2/167

(58) **Field of Classification Search**

CPC D03D 15/12; D03D 15/00; D03D 13/004; D03D 25/00; D06M 2200/30; A41D 31/0022; A41D 1/02; A41D 31/0027; D04B 21/04; D10B 2331/021; D10B 2501/04; A62B 17/003

USPC .... 2/458; 139/383 R, 420 R, 420 A

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,333,824	A		11/1943	Schoepf	
2,696,723	A		12/1954	Frith	
3,097,442	A		7/1963	Willingham	
3,806,959	A		4/1974	Gross	
4,615,934	A		10/1986	Ellison	
4,668,234	A		5/1987	Vance et al.	
4,920,000	A		4/1990	Green	
5,141,542	A		8/1992	Fangeat et al.	
5,150,476	A	*	9/1992	Statham et al.	2/93
5,323,815	A		6/1994	Barbeau et al.	
5,527,597	A	*	6/1996	Stanhope et al.	442/184
5,539,928	A		7/1996	Aldridge	
5,640,718	A		6/1997	Aldridge	
5,685,015	A		11/1997	Aldridge	
5,694,981	A	*	12/1997	Stanhope et al.	139/383 R
5,724,673	A		3/1998	Aldridge	
5,727,401	A	*	3/1998	Statham	66/176
5,819,316	A		10/1998	Aldridge	
5,824,614	A		10/1998	Gadoury	
5,830,574	A		11/1998	Gadoury	
5,849,648	A		12/1998	Kent et al.	
5,858,888	A		1/1999	Underwood	
5,885,307	A		3/1999	Gadoury	
5,891,813	A		4/1999	Gadoury	
5,920,905	A		7/1999	Aldridge	
5,928,971	A	*	7/1999	Ellis et al.	442/76
6,132,476	A	*	10/2000	Lunsford et al.	8/531
6,247,179	B1		6/2001	Underwood	
6,430,754	B1		8/2002	Taylor et al.	
6,547,835	B1	*	4/2003	Lunsford et al.	8/531
6,626,964	B1	*	9/2003	Lunsford et al.	8/531
6,668,868	B2		12/2003	Howland et al.	
6,693,052	B2		2/2004	Howland	
6,735,789	B2	*	5/2004	Kelleher et al.	2/458
6,818,024	B2	*	11/2004	Lunsford et al.	8/531
6,840,288	B2		1/2005	Zhu et al.	
6,861,378	B2		3/2005	Cunningham	
6,867,154	B1	*	3/2005	Lunsford et al.	442/136
6,974,785	B1		12/2005	Barbeau	
7,013,496	B2	*	3/2006	Dunn	2/458
7,065,950	B2		6/2006	Zhu et al.	
7,073,538	B2		7/2006	Bhatnagar	
7,156,883	B2		1/2007	Lovasic et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

AU	2005200963	A1	3/2005
KR	20060122840	A	11/2006
KR	20070012391	A	1/2007
WO	02/052077	A2	7/2002
WO	2004/088023	A2	10/2004
WO	2006/043958	A1	4/2006
WO	2007/061423	A2	5/2007
WO	2010091476		8/2010

OTHER PUBLICATIONS

Partial Search Report, PCT Application No. PCT/US2009/030111, mailed Apr. 23, 2009.
International Search Report and Written Opinion, PCT Application No. PCT/US10/35399, mailed Jul. 15, 2010.
International Search Report and Written Opinion, PCT Application No. PCT/US2012/066227, mailed Feb. 28, 2013.
"Lion Ready for Action", Dec. 21, 2011.
"Tools & Technologies: Fire Service Prepares for Change in PPE Technology", Feb. 1, 2012.

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(57) **ABSTRACT**

Flame resistant fabrics are formed by warp and fill yarns having different fiber contents. The fabrics are constructed, for example, by selection of a suitable weaving pattern, such that the body side of the fabric and the face side of the fabric have different properties. The fabrics described herein can be printable and dyeable on both sides of the fabric and are suitable for use in military and industrial garments. Methods of forming flame resistant fabrics, and methods for forming garments from the fabrics, are also described.

20 Claims, No Drawings

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,284,398	B2	10/2007	Hubner	
7,393,800	B2 *	7/2008	Corner	442/302
7,402,538	B2	7/2008	Bader et al.	
7,589,036	B2 *	9/2009	Corner et al.	442/301
7,634,819	B2	12/2009	Grey	
7,676,855	B2 *	3/2010	Dunn	2/458
7,854,017	B2 *	12/2010	Laton	2/81
7,862,865	B2 *	1/2011	Truesdale et al.	427/430.1
RE42,209	E *	3/2011	Lunsford et al.	442/136
8,017,532	B2	9/2011	Okada	
8,327,469	B2	12/2012	Curtis	
8,347,420	B2	1/2013	Kruzsewski et al.	
2001/0009832	A1	7/2001	Shaffer et al.	
2002/0016985	A1 *	2/2002	Kelleher et al.	2/458
2002/0069453	A1 *	6/2002	Kelleher et al.	2/458
2003/0082972	A1 *	5/2003	Monfalcone et al.	442/138
2003/0167580	A1 *	9/2003	Lunsford et al.	8/531
2003/0226612	A1	12/2003	Zhu et al.	
2003/0228812	A1 *	12/2003	Stanhope et al.	442/49
2004/0029473	A1	2/2004	McKee et al.	
2004/0045103	A1 *	3/2004	Lunsford et al.	8/531
2004/0065072	A1	4/2004	Zhu et al.	
2004/0152378	A1 *	8/2004	Stanhope et al.	442/5
2005/0032449	A1	2/2005	Lovasic et al.	
2005/0050619	A1 *	3/2005	Dunn	2/458
2005/0060820	A1 *	3/2005	Lunsford et al.	8/518
2005/0064020	A1	3/2005	Schuette	
2005/0245163	A1	11/2005	Aneja et al.	
2005/0287364	A1	12/2005	Zhu et al.	
2006/0040575	A1 *	2/2006	Kelleher et al.	442/73
2006/0084337	A1 *	4/2006	Corner et al.	442/203
2006/0143809	A1 *	7/2006	Dunn	2/458
2006/0264136	A1 *	11/2006	Chiantese	442/304
2007/0184737	A1 *	8/2007	Corner et al.	442/203
2007/0249250	A1	10/2007	Servajean	
2008/0057807	A1 *	3/2008	Tutterow et al.	442/1
2008/0086798	A1 *	4/2008	Allen et al.	2/458
2008/0148468	A1 *	6/2008	Laton et al.	2/455
2008/0152888	A1 *	6/2008	Tutterow et al.	428/221
2008/0227352	A1 *	9/2008	Byles et al.	442/312
2008/0295232	A1 *	12/2008	Truesdale et al.	2/458
2009/0030111	A1	1/2009	Barnes et al.	
2009/0139016	A1	6/2009	Zhu et al.	
2009/0178186	A1 *	7/2009	Truesdale	2/455
2009/0226653	A1	9/2009	Harris et al.	
2009/0255038	A1	10/2009	Curtis	
2010/0024103	A1 *	2/2010	Kelleher et al.	2/458
2010/0075557	A1	3/2010	Shteiyer	
2010/0112312	A1 *	5/2010	Tutterow et al.	428/196
2010/0143683	A1	6/2010	Chiou	
2011/0010827	A1 *	1/2011	Stanhope et al.	2/458
2011/0023206	A1	2/2011	Dunn	
2011/0138523	A1	6/2011	Layson, Jr. et al.	
2012/0031783	A1	2/2012	Fay, III et al.	
2012/0090080	A1 *	4/2012	Stanhope et al.	2/458
2012/0183747	A1	7/2012	Bader	
2012/0210481	A1	8/2012	Rock	
2013/0216810	A1	8/2013	Hines et al.	

* cited by examiner

FLAME RESISTANT FABRIC WITH ANISOTROPIC PROPERTIES

RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 12/783,368, filed May 19, 2010, which claims the benefit of U.S. Provisional Patent Application Ser. No. 61/179,461, filed May 19, 2009, each of which is incorporated by this reference herein in their entireties.

FIELD OF THE INVENTION

This invention relates to a flame resistant fabric, and more specifically to a flame resistant fabric having different properties on each side of the fabric.

BACKGROUND OF THE INVENTION

Flame resistant fabrics, and in particular garments, are desirable in many military and industrial applications. Military personnel in the field, for example, can be exposed to flash fire or electrical arc situations and it is therefore desirable that their combat uniforms provide protection from such conditions. While many fabrics provide suitable flame resistance properties and can be incorporated into combat uniforms and other industrial protective gear, flame resistance is not the only requirement for such fabrics. Other factors, such as comfort, durability, thermal performance, printability, dyeability and cost are also considered when evaluating the suitability of a fabric for military or industrial applications.

Not all protective fabrics are the same. Fabrics made entirely from inherently flame resistant fibers such as para-aramids and meta-aramids, for example, provide excellent flame resistance but garments made therefrom do not naturally absorb water and thus have poor moisture management properties. These garments can thus be uncomfortable on the skin of the wearer. This drawback can be tempered by the inclusion of softer and more absorbent fiber, such as cellulosic fibers. Such fibers, however, are less durable than inherently flame resistant fibers.

Fabrics made from blends of different fibers can have some of the beneficial properties of the individual fibers, but with those benefits come the drawbacks of each fiber. Thus, it has traditionally been necessary to select fiber blends for a fabric to maximize the desirable properties in the fabric while minimizing the undesirable effects of these fibers. This balancing act has not always been successfully performed.

Thus, a need exists for a fabric in which desirable properties can more easily be imparted to the fabric and in which negative effects due to use of particular fibers can be minimized.

SUMMARY OF EMBODIMENTS OF THE INVENTION

The terms “invention,” “the invention,” “this invention” and “the present invention” used in this patent are intended to refer broadly to all of the subject matter of this patent and the patent claims below. Statements containing these terms should be understood not to limit the subject matter described herein or to limit the meaning or scope of the patent claims below. Embodiments of the invention covered by this patent are defined by the claims below, not this summary. This summary is a high-level overview of various aspects of the invention and introduces some of the concepts that are further described in the Detailed Description section below. This

summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed subject matter. The subject matter should be understood by reference to appropriate portions of the entire specification of this patent, any or all drawings and each claim.

The present invention is directed to flame resistant fabrics formed by warp and fill yarns having different fiber contents. The fabrics are constructed such that the body side of the fabric (the side of the fabric on the side of the body of the wearer (assuming the fabric will be incorporated into a garment)) and the face side of the fabric (the side of the fabric facing away from the body of the wearer) have different properties. For example, it may be desirable for the body side of the fabric to be relatively softer and more absorbent, and thus more comfortable, for contact with the skin of the wearer, and for the face side of the fabric to have improved durability at the expense of comfort (since comfort is not as much of a consideration on the face side of the fabric).

In one embodiment, a flame resistant fabric includes warp yarns and fill yarns and has a body side and a face side. Either of the warp yarns or the fill yarns comprises a first fiber content and the other of the warp yarns or the fill yarns comprises a second fiber content different from the first fiber content. Fibers of the first fiber content are predominantly exposed on the body side of the fabric; and fibers of the second fiber content are predominantly exposed on the face side of the fabric.

In some embodiments, the warp yarns and fill yarns can have different amounts of the same fibers or, in yet other embodiments, can have different fibers or different blends of fibers.

In still another embodiment, the body fibers and the face fibers are woven in the fabric. The weave can be one or more of a twill, satin or sateen weave.

In other embodiments, garments formed from the flame resistant fabric described above are provided. The garments are suitable for use in military and industrial applications, and are particularly suitable for use in a military battle dress uniform.

In yet other embodiments, methods of making the flame resistant fabric and methods of making garments from the flame resistant fabric are provided.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

The subject matter of embodiments of the present invention is described here with specificity to meet statutory requirements, but this description is not necessarily intended to limit the scope of the claims. The claimed subject matter may be embodied in other ways, may include different elements or steps, and may be used in conjunction with other existing or future technologies. This description should not be interpreted as implying any particular order or arrangement among or between various steps or elements except when the order of individual steps or arrangement of elements is explicitly described.

The fabrics described herein have anisotropic properties, i.e., they have different properties on the body side of the fabric and the face side of the fabric. This is accomplished by providing warp yarns having a first fiber content and fill yarns having a second fiber content different from the first fiber content. In other words, either the warp yarns and fill yarns do not have identical fibers or blends of fibers, or the warp yarns and fill yarns contain different amounts of the same fibers. By way of example, the warp yarns could contain 30% FR cel-

lulosic fibers and 70% para-aramid fibers and the fill yarns could contain 65% FR cellulosic fibers and 35% para-aramid fibers (i.e., identical fibers but in different amounts). Alternatively, the warp yarns could contain 65% modacrylic fibers and 35% para-aramid fibers and the fill yarns could contain 65% FR cellulosic fibers and 35% para-aramid fibers (i.e., different blends of fibers). Exemplary fiber blends are discussed in more detail below.

Suitable fiber blends according to the present invention include any of the fiber blends contemplated in U.S. patent application Ser. No. 11/847,993 (the "'993 Application"), entitled "Flame Resistant Fabrics and Garments Made From Same" and published as US-2008-0057807-A1, as well as U.S. Pat. No. 6,867,154 (the "'154 Patent"), entitled "Patterned, Flame Resistant Fabrics and Method For Making Same" and issued Mar. 15, 2005, the entire contents of each of which are herein incorporated by reference.

In some embodiments, the warp yarns and the fill yarns are formed from fibers or blends of fibers that include one or more of modacrylic fibers, cellulosic fibers (natural and synthetic, FR and non-FR), inherently FR fibers (e.g., aramids, PBI, PBO, etc.) and other non-FR fibers.

Suitable modacrylic fibers include, but are not limited to, PROTEX™ fibers (including but not limited to PROTEX W™, PROTEX C™and PROTEX M™ fibers) available from Kaneka Corporation of Osaka, Japan, and SEF™ fibers, available from Solutia.

The cellulosic fibers may be natural or synthetic. Suitable natural cellulosic fibers include, but are not limited to, cotton, flax, hemp or blends thereof. The synthetic cellulosic fibers may be, but are not limited to, rayon, FR rayon, lyocell, cellulose acetate, or blends thereof. An example of a suitable rayon fiber is MODAL™ by Lenzing, available from Lenzing Fibers Corporation. Examples of lyocell fibers include TENCEL™, available from Lenzing Fibers Corporation. Examples of FR rayon fibers include Lenzing FR™, also available from Lenzing Fibers Corporation.

Cellulosic fibers (natural or synthetic) are not naturally resistant to flame. To increase the flame resistance of these fibers, one or more flame retardants may be incorporated into the fibers during the manufacturing process. Effective flame retardants include phosphorus compounds and antimony compounds. However, the cellulosic fibers need not always be rendered flame resistant. For example, if the cellulosic fibers are being blended with FR modacrylic fibers that control and counteract the flammability of the cellulosic fibers to prevent such fibers from burning, they need not be flame resistant. Use of non-FR cellulosic fibers instead of FR cellulosics significantly reduces the cost of fabrics made from such fibers. Again, however, both FR and non-FR cellulosic fibers are contemplated herein.

Other non FR fibers (natural or synthetic) can also be used as long as they are added in low enough levels (typically less than about 15% by weight) such that they will not detrimentally affect the thermal characteristics of fabric. Examples of such non-flame resistant fibers include, but are not limited to: (1) anti-static fibers to dissipate or minimize static, (2) antimicrobial fibers, (3) stretch fibers (e.g., spandex), (4) other fibers such as nylon and/or polyester fibers, and/or (5) other fibers that are added to the blends to improve the abrasion resistance of the fabrics.

Suitable inherently FR fibers include, but are not limited to, para-aramid fibers, meta-aramid fibers, polybenzimidazole (PBI) fibers, polybenzoxazole (PBO) fibers, melamine fibers, carbon fibers, pre-oxidized acrylic fibers, polyacrylonitrile (PAN) fibers, TANLON™ (available from Shanghai Tanlon Fiber Company), polyamide-imide fibers such as KERMEL™, and blends thereof. Examples of para-aramid fibers include KEVLAR™ (available from DuPont), TECHNORA™ (available from Teijin Twaron BV of Arnheim, Netherlands), and TWARON™ (also available from Teijin Twaron BV). Examples of meta-aramid fibers include NOMEX™ (available from DuPont) and CONEX™ (available from Teijin). An example of melamine fibers is BASOFIL™ (available from Basofil Fibers). An example of PAN fibers is Panox® (available from the SGL Group). As explained above, such inherently FR fibers impart the requisite thermal stability to the blend to enable fabrics made from such blends to be used in protective garments.

The yarns can be formed in conventional ways well known in the industry. The yarns may be spun yarns and can comprise a single yarn or two or more individual yarns that are twisted, or otherwise combined, together. In one embodiment, the yarns are air jet spun yarns. Typically, the yarns comprise one or more yarns that each have a yarn count in the range of approximately 5 to 60 cc. In other embodiments, the yarns comprise two yarns that are twisted together, each having a yarn count in the range of approximately 10 to 60 cc.

The FR fabrics formed with the blends disclosed herein preferably, but not necessarily, have a weight between approximately 3-12 ounces per square yard ("osy") and more preferably between approximately 5-9 osy.

As discussed above, it may be desirable for the body side of the fabric to be relatively softer and more absorbent, and thus more comfortable, for contact with the skin of the wearer, and for the face side of the fabric to have improved durability at the expense of comfort (since comfort is not as much of a consideration on the face side of the fabric). Such fabric constructions can be achieved using weaving and knitting processes.

In a typical weaving process according to the present invention, the fibers on the face side of the fabric will predominantly comprise the warp yarns and the fibers on the body side of the fabric will predominantly comprise the fill yarns. The fabric may be constructed with the warp and fill yarns in a variety of ways, including but not limited to, one or more of twill weave (2×1, 3×1, etc.), satin weave (4×1, 5×1, etc.), and sateen weave constructions, or any other weave where yarn is predominantly more on one side of the fabric than the other side of the fabric. A person skilled in the art would be familiar with and could utilize suitable fabric constructions.

Notwithstanding the above, it will be understood that the fabric can be constructed such that the fibers on the face side of the fabric predominantly comprise the fill yarns and the fibers on the body side of the fabric predominantly comprise the warp yarns. In such a construction, a weave will be selected such that a comfortable fiber blend (e.g., a blend including one or more cellulosic fibers) is predominantly exposed on the body side of the fabric. A person skilled in the art would understand how to select an appropriate weave pattern so as to locate predominantly more of either the warp or fill yarns on one side of the fabric.

It should be noted that plain or ripstop weaves will typically not be used, because in such weaves there are an equal number of warp yarns and fill yarns on each side (i.e., the body side and face side) of the fabric, and both sides of the fabric would thus have the same properties.

It will also be recognized that any woven fabric will have both warp and fill yarns visible on each side of the fabric. Fabrics woven in accordance with the present invention, however, are woven such that more of either the warp yarns or the fill yarns are located on the face side of the fabric, and thus more of either the fill yarns or the warp yarns are located on

the body side of the fabric. Thus, in an exemplary fabric construction in which more of the warp yarns are located on the face side of the fabric and more of the fill yarns are located, or exposed, on the body side of the fabric, the warp yarns are "predominantly" located, or exposed, on the face side of the fabric (even though some warp yarns would be visible from the body side of the fabric) and the fill yarns are "predominantly" located, or exposed, on the body side of the fabric (even though some fill yarns would be visible from the face side of the fabric).

In other embodiments of the invention, a knit fabric that has different properties on each side of the fabric can be constructed. Such a fabric could be constructed using a double-knit circular knitting machine These machines have two needles, a dial needle and a cylinder needle, that work together to form the double-knit fabric. When utilized to make fabrics according to embodiments of the invention, different yarns can be used in each of the dial needle and cylinder needle such that the two yarns become inter-stitched with one yarn predominantly exposed on one side of the knit fabric and the other yarn predominantly exposed on the other side of the fabric. A yarn comprising cellulosic fibers could be knit into a fabric by at least one of the dial needle or cylinder needle so that a cellulosic-containing yarn is predominantly exposed on the body side of the fabric. Garments could be constructed from knit fabrics according to the embodiments described above.

As discussed above, in some embodiments the yarns of the present invention are formed from fibers or blends of fibers that include one or more of modacrylic fibers, cellulosic fibers (natural and synthetic, FR and non-FR), inherently FR fibers (e.g., aramids, PBI, PBO, etc.) and other non-FR fibers. In a more specific embodiment, a blend of fibers intended for a yarn that is predominantly exposed on the body side of a fabric includes approximately 20-80% by weight cellulosic fibers, approximately 0-55% by weight modacrylic fibers, approximately 0-80% by weight inherently FR fibers, and approximately 0-15% by weight other non-FR fibers (such as nylon).

In yet another embodiment, fibers or a blend of fibers intended for a yarn that is predominantly exposed on the face side of a fabric includes 0-100% of one or more of modacrylic fibers, cellulosic fibers (natural and synthetic, FR and non-FR), inherently FR fibers and other non-FR fibers. Thus, any suitable fiber or blend of fibers can be selected as long as the overall fabric remains flame resistant.

Dyeing and printing of such fabrics may be carried out in accordance with standard methods, all of which are known to those of skill in the art. Such methods include, but are not limited to, those dyeing and/or printing methods disclosed in the '154 Patent and the '993 Application. Although it will be recognized that certain fibers and fiber blends are more dyeable than others, it is desirable that both sides of the fabric be at least somewhat dyeable and printable. If only one side (i.e., the face side) of the fabric were dyeable and/or printable, the fabric is susceptible to "grin-through" or contrasting shades from the non-dyed/non-printed fibers that, though predominantly on the body side of the fabric, would also be at least partially visible on the face side of the fabric. Moreover, it is more difficult to produce a fabric that will pass military infrared reflectance requirements if the fabric has "grin through." Another benefit of having a garment, such as a shirt, that includes a fabric that is dyed and/or printed on both sides is the wearer can roll their shirt sleeves up and still have color or a print pattern on the body side of the fabric.

Suitable dyes for the fabrics described herein include direct, reactive, and vat dyes. Of these, vat dyes may be

particularly useful for fabrics of the present invention because they satisfy military requirements GL-PD-07-12, Revision 4 (as referenced below).

In yet other embodiments, the fabric described herein may include at least 10% para-aramid fibers (including fibers in both the warp and fill yarns), and may include up to 30% para-aramid fibers.

In some embodiments, the yarns predominantly on the face side of the fabric (e.g., the warp yarns) include no more than about 15% para-aramid fibers and the yarns predominantly on the body side of the fabric (e.g., the fill yarns) include no more than about 60% para-aramid fibers and at least about 20% comfort fibers such as the cellulosic fibers described above. All, some or none of the comfort fibers may be treated with a flame retardant, as long as the overall fabric remains flame resistant and meets flame resistant standards described herein.

Fabrics described herein and dyed as described above may also have improved colorfastness as compared to previously known fabrics. Fabrics formed from fiber blends of the construction described in the previous paragraph may have relatively high para-aramid fiber content on the body side of the fabric (up to about 60%). Para-aramid fibers are desirable because they are inherently flame resistant and because they are high tenacity fibers that impart strength to the resulting yarns and fabrics. Para-aramid fibers, however, have a tendency to fibrillate after washing, and fibrillation of fiber blends having a high para-aramid content may impart a frosted appearance to the yarn. While such a frosted appearance may not be desirable if these blends were predominantly on the face side of the fabric, the frosted appearance is not a substantial issue when it occurs predominantly on the body side of the fabric.

In contrast to para-aramid fibers, meta-aramid fibers do not fibrillate after washing As a result, it may be desirable to include meta-aramid fibers on the face side of the fabric for improved after-wash appearance.

Fabrics formed in accordance with the embodiments described herein preferably meet certain industrial and/or military standards for flame resistance. In particular, the fabrics preferably have an after-flame of less than 2 seconds and less than a 4-inch char length when tested in accordance with ASTM D 6413 ("Standard Test Method for Flame Resistance of Textiles"). In addition, such fabrics preferably comply with National Fire Protection Association ("NFPA") 2112 ("Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire"). In other embodiments, fabrics according to the present invention satisfy the U.S. Army requirements for the flame resistant Advanced Combat Uniform as specified in GL-PD-07-12, Revision 4. These test methods and standards are incorporated by reference herein in their entirety.

The fabrics with anisotropic properties described herein, having different properties on the body side and face side of the fabric, can thus be customized so that a particular desirable property can be achieved on one side of the fabric without substantially affecting the properties on the other side of the fabric. For example, a cost effective fabric having desirable comfort, flame resistance, durability, thermal stability, and other properties can be optimized for one side of the fabric without substantially affecting other desirable properties on the other side of the fabric.

In addition, while the fibers described above for the warp yarns and fill yarns are primarily described as being a blend of fibers, it will be recognized that in some embodiments these yarns need not be blended at all. In other words, the warp yarns could be 100% of one fiber type and/or the fill yarns

could be 100% of another fiber type. The warp and fill yarns should not, of course, each have 100% of the same fiber (e.g., 100% FR Rayon for both the warp and fill yarns), otherwise no matter how the fabric is woven both sides of the fabric would have the same properties.

The fabrics described herein can be incorporated into military or industrial garments, including but not limited to combat uniforms, shirts, jackets, trousers and coveralls.

In another embodiment, a method of making a fabric having anisotropic properties is provided. In the method, a woven fabric according to embodiments described above is formed such that the warp yarns have a fiber content that is different than the fiber content of the fill yarns. In other words, either the warp yarns and fill yarns do not have identical fibers or blends of fibers, or the warp yarns and fill yarns contain different amounts of the same fibers.

In yet another embodiment, a method of making a garment from a fabric having anisotropic properties is provided. In the method, a fabric formed according to embodiments described above is incorporated into a garment.

The present invention is further illustrated by way of the examples contained herein, which are provided for clarity of understanding. The exemplary embodiments should not to be construed in any way as imposing limitations upon the scope thereof. On the contrary, it is to be clearly understood that resort may be had to various other embodiments, modifications, and equivalents thereof which, after reading the description herein, may suggest themselves to those skilled in the art without departing from the spirit of the present invention and/or the scope of the appended claims.

EXAMPLES

Fabrics having the fiber blends listed in Table 1 were prepared:

TABLE 1

Fabric No.	Warp blend (predominantly face side)	Fill blend (predominantly body side)	Weave
1	50/45/5 FR rayon/T-450 Nomex ™/ para-aramid	40/30/20/5 Modacrylic/Tencel ™/ para-aramid/nylon	3 × 1 Twill
2	50/35/5/10 FR rayon/T-450 Nomex ™/ para-aramid/nylon	65/25/10 FR rayon/para-aramid/ nylon	3 × 1 Twill
3	55/35/10 FR rayon/Nomex IIIA*/nylon	50/50 FR rayon/para-aramid	3 × 1 Twill
4	55/35/10 FR rayon/Nomex IIIA*/nylon	50/40/10 FR rayon/para-aramid/ nylon	3 × 1 Twill
5	55/35/10 FR rayon/Nomex IIIA*/nylon	50/50 FR rayon/para-aramid	2 × 1 Twill
6	55/35/10 FR rayon/Nomex IIIA*/nylon	50/40/10 FR rayon/para-aramid/ nylon	2 × 1 Twill

*Nomex IIIA contains 93/5/2 meta-aramid fibers/para-aramid fibers/antistatic fibers

The warp and fill yarns of Fabric Nos. 1-6 each had a different fiber content, and the fill blend (i.e., predominantly exposed on the body side of the fabric) included cellulosic fibers (FR rayon).

The fabrics of Examples 3-6 were made using 64% warp yarns and 36% fill yarns. The fabrics of Examples 3 and 5 thus have approximately 19% para-aramid fibers (64% of 1.75% para-aramid fibers in the warp blend (5% of 35%) and 36% of 50% para-aramid fibers in the fill blend), and the fabrics of Examples 4 and 6 thus have approximately 16% para-aramid fibers (64% of 1.75% para-aramid fibers in the warp blend and 36% of 40% para-aramid fibers in the fill blend). Both sides of these fabrics are dyeable and/or printable to dark shades, and any frosting appearance due to washing in the para-aramid fibers is most pronounced in the fill blend, which is predominantly located on the body side of the fabric. The fabrics thus have good after-wash appearance.

Different arrangements of the components described above, as well as components and steps not described are possible. Similarly, some features and subcombinations are useful and may be employed without reference to other features and subcombinations. Embodiments of the invention have been described for illustrative and not restrictive purposes, and alternative embodiments will become apparent to readers of this patent. Accordingly, the present invention is not limited to the embodiments described above, and various embodiments and modifications can be made without departing from the scope of the claims below.

We claim:

1. A flame resistant fabric formed of warp yarns and fill yarns and comprising a body side and a face side, wherein:

(a) either of the warp yarns or the fill yarns comprise a first fiber content;

(b) the other of the warp yarns or the fill yarns comprise a second fiber content different from the first fiber content;

(c) fibers of the first fiber content are predominantly exposed on a body side of the fabric;

(d) fibers of the second fiber content are predominantly exposed on a face side of the fabric; and

(e) the fabric comprises at least 10% para-aramid fibers and more of the para-aramid fibers are located in the first fiber content than in the second fiber content.

2. The fabric of claim **1**, wherein the fabric is dyeable and printable.

3. The fabric of claim **1**, wherein the warp yarns and fill yarns comprise different amounts of the same fibers.

4. The fabric of claim **1**, wherein the warp yarns and fill yarns comprise different fibers or different blends of fibers.

5. The fabric of claim **1**, wherein the warp yarns and fill yarns are woven using one or more of a twill weave, a satin weave and a sateen weave.

6. The fabric of claim **1**, wherein the first fiber content comprises approximately 20-80% cellulosic fibers.

7. The fabric of claim **6**, wherein the first fiber content further comprises one or more of modacrylic fibers, inherently flame resistant fibers other than the para-aramid fibers, and nylon fibers.

8. A garment formed from the fabric of claim **1**.

9. The garment of claim **8**, wherein the garment is a military combat uniform.

10. The fabric of claim **1**, wherein the fabric has an afterflame of less than 2 seconds and less than a 4-inch char length when tested in accordance with ASTM D 6413.

11. The fabric of claim **1**, wherein the fabric complies with NFPA 2112.

12. The fabric of claim **1**, wherein the fabric complies with the physical requirements set forth in GL-PD-07-12, Revision 4.

13. A method for forming a flame resistant fabric comprising a body side and a face side, the method comprising:

(a) providing a plurality of first yarns, each having a first fiber content;

(b) providing a plurality of second yarns, each having a second fiber content different from the first fiber content;

(c) weaving the plurality of first yarns with the plurality of second yarns so that:

i. fibers of the first fiber content are predominantly exposed on the body side of the fabric;

ii. fibers of the second fiber content are predominantly exposed on the face side of the fabric; and

wherein the fabric comprises at least 10% para-aramid fibers and more of the para-aramid fibers are located in the first fiber content than in the second fiber content.

14. The method of claim **13**, further comprising dyeing or printing the fabric.

15. The method of claim **13**, wherein the first yarns and second yarns comprise different amounts of the same fibers.

16. The method of claim **13**, wherein the first yarns and second yarns comprise different fibers or different blends of fibers.

17. The method of claim **13**, wherein weaving the plurality of first yarns with the plurality of second yarns comprises using one or more of a twill weave, a satin weave and a sateen weave.

18. The method of claim **13**, wherein the first fiber content comprises approximately 20-80% cellulosic fibers.

19. The method of claim **18**, wherein the first fiber content further comprises one or more of modacrylic fibers, inherently flame resistant fibers other than the para-aramid fibers, and nylon fibers.

20. A garment formed from fabric produced according to the method of claim **13**.

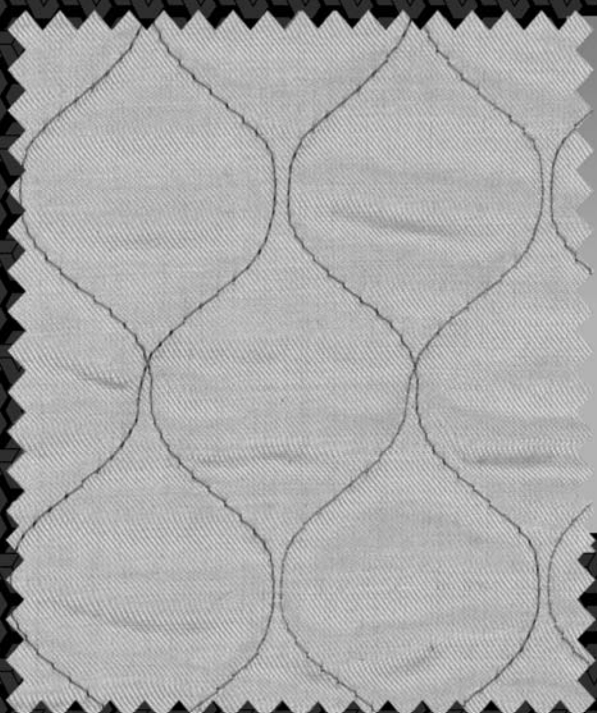
* * * * *

Glide™ THERMAL LINERS

SLICKER, SOFTER…
THE WAY A LINER SHOULD FEEL

The slick low friction properties of Glide™ mean added freedom of movement and less working stress for a more comfortable feel in your turnout gear. This low friction capability is a result of our patented weave…the only face cloth with 60% DuPont™ Kevlar® using Safety Components' Filament Twill Technology™.

In addition to low friction, Glide provides the ultimate in moisture management as it wicks perspiration from the body and dries quickly – keeping you cooler, drier and more comfortable.

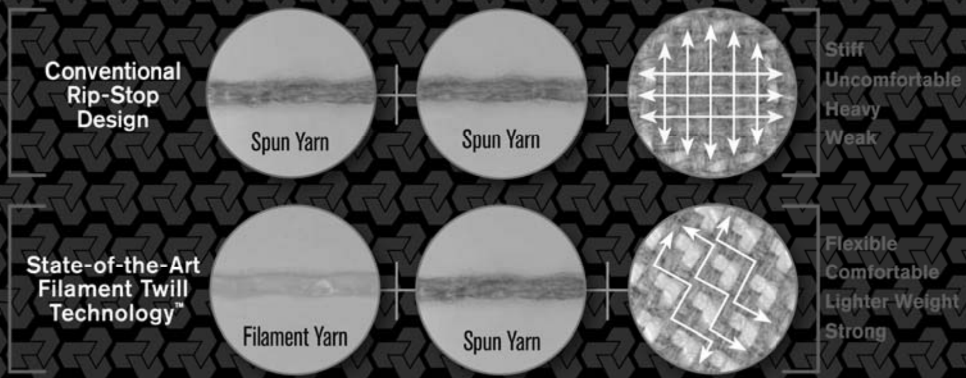


“70% of the Top 10 Metro Cities specify Safety Components protective fabrics.”

SAFETY COMPONENTS

PROVEN PROTECTION. PROVEN PERFORMANCE. PROVEN DURABILITY.

Turnout Gear Fabric Technologies



Glide™ THERMAL LINERS

FACE CLOTH: 60% DuPont™ Kevlar® filament
40% spun yarn
(DuPont™ Nomex®, Lenzing FR®)

AVAILABLE BATTINGS:
- Multi-layer meta/para-aramid spunlace
- PBI G2™ multi-layer PBI/aramid spunlace
- 4 oz. virgin needlepunched meta-aramid batting

Look Beyond the Surface

If you are searching for optimum slickness and freedom of movement, you need to consider yarn construction and design. That's when you'll realize all thermal liners aren't engineered for the work you do. When you look beyond the surface, it's easy to understand how Glide™ (60% DuPont Kevlar filament) outperforms conventional spun-filament liner systems (typically 25-50% filament) in terms of slickness, comfort, and freedom of movement.

Consider the illustrative photos below: Glide (left) with DuPont Kevlar filament utilizing Safety Components' patented Filament Twill Technology; and Tencate Quantum3D® (right) using a traditional spun-filament blend. So, what is the difference?

A microscopic analysis shows Glide (Fig. 1) with an abundance of strategically woven DuPont Kevlar filament on the surface of the fabric – a combination leading to significant advantages in slickness for freedom of movement, lubricity for comfort, and strength for durability. Comparatively, Tencate Quantum3D (Fig. 2) has an abundance of coarse, loose, and scruffy spun yarns on the surface of the fabric – a combination leading to more friction and less comfort.

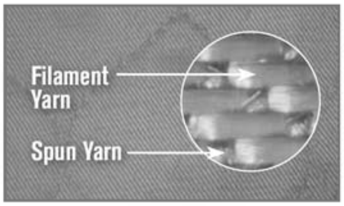


Fig. 1: Glide

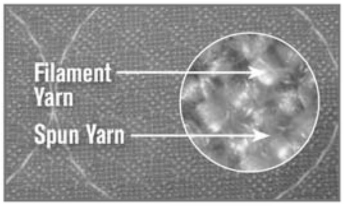
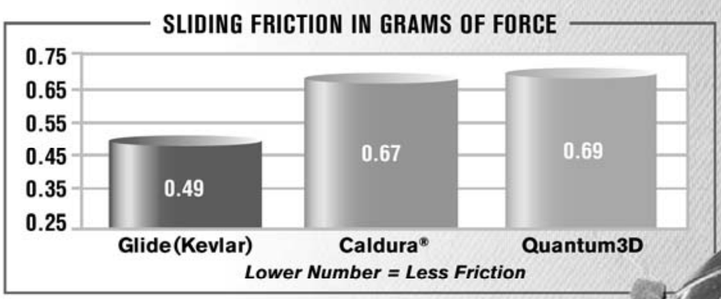


Fig. 2: Quantum3D

Optimum Moisture Management

Glide is engineered to significantly reduce stress, reduce friction and provide excellent moisture management. Glide's special weave allows this thermal liner to move sweat away from your body for greater comfort and release that moisture for quick drying time…all this while maintaining the freedom of movement you need to get the job done.



Specify Glide in one of the following combinations:

Glide 2-Layer – 7.4 oz.
Glide face cloth quilted to 2-layers of spunlace (one-layer of 1.5 oz. meta/para-aramid spunlace and one-layer of 2.3 oz. meta/para-aramid spunlace).

Glide with PBI G2 – 6.8 oz.
Glide face cloth quilted to one-layer of 1.4 oz. and one-layer of 1.8 oz. PBI/aramid spunlace batting.

Glide Pure – 7.6 oz.
Glide face cloth quilted to one-layer of virgin (pure) needlepunched meta/para-aramid fiber with a weight of 4 oz.

40 Emery Street ▪ Greenville, SC 29605 ▪ 800-896-6926 ext. 25 ▪ www.safetycomponents.com

Safety Components maintains ISO 9001:2000, TS 16949 and ISO 14001 certifications. Our fabric testing laboratories are ISO 1725 approved, ASTM (North America), DIN (Europe), JIS (Asia), and NFPA certified. Throughout our 100 year history, Safety Components has developed a reputation for product quality, product innovation, product diversity and on-time delivery.

A Proud Supporter of National Fallen Firefighters Foundation®

DuPont™ Nomex. | DuPont™ Kevlar.

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